US Army Corps
of Engineers
Detroit District

FEASIBILITY STUDY FOR THE BOARDMAN RIVER

GRAND TRAVERSE COUNTY, MICHIGAN

APPENDIX B - ECONOMIC ANALYSIS

GREAT LAKES FISHERIES AND ECOSYSTEM RESTORATION PROGRAM

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FEASIBILITY STUDY FOR THE BOARDMAN RIVER
ECONOMICS ANALYSIS

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1 Introduction

The Boardman River Feasibility Study was conducted by the U.S. Army Corps of Engineers (USACE), Detroit District, under the authority of Section 506 (Great Lakes Fishery and Ecosystem Restoration Program) of the Water Resources Development Act of 2000 (Public Law 106-541). The Boardman River originates in Grand Traverse and Kalkaska Counties, MI, and flows approximately 49 miles before entering West Grand Traverse Bay at Traverse City, MI. There are three dams along the waterway: Union Street Dam at river mile 1.1, Sabin Dam at river mile 5.3, and Boardman Dam (also known as Keystone Dam) at river mile 6.1. The dams disrupt the Boardman River ecosystem through habitat fragmentation and degradation, impacts to sediment transport, and thermally induced species disruption. The well-documented effect over the last three decades is a reduction in populations of trout and other aquatic species immediately upstream and downstream of the dams.

Project objectives include reconnecting and restoring tributary habitat, allowing unimpeded movement of woody debris and sediment materials through the river system, negating thermal disruption, and restoring the natural balance between coldwater species. These objectives must be accomplished without transporting pollutants into the Grand Traverse Bay of Lake Michigan or allowing upstream migration of invasive aquatic species.

The purpose of this appendix is to explain the methodology applied in the economic analysis of the ecosystem restoration measures and alternatives considered in the study.

2 Socioeconomic Analysis

A socioeconomic analysis was conducted to provide a better understanding of the characteristics of the communities in the study area. Having a better understanding of the communities can help to determine how a project could have an impact on residents.

Grand Traverse County encompasses the Boardman Lake and Sabin Pond. Adjacent to Grand Traverse County is Kalkaska County, which contains much of the upper North and South Branch of the Boardman River. The Boardman River offers recreation opportunities such as fishing, canoeing, kayaking, and hunting. About 36 river miles are designated as Blue Ribbon river sections for trout fishing. The Boardman River is considered to be one of the top 10 best trout streams in Michigan (Huggler and Barfknecht 1995).

The Boardman Valley Nature Preserve is adjacent to Sabin Pond and includes over 100 acres for hiking, mountain biking, nature watching, hunting, and fishing. The Natural Education Reserve abuts the Boardman Valley Nature Preserve to the south and has 505 acres and 7 miles of trails along both banks of the Boardman River.

Table 1 presents demographic and socioeconomic data from the 2010 U.S. Census for Grand Traverse County, Kalkaska County, and Michigan. The percentage change is the percentage increase/decrease from the 2000 U.S. Census. Michigan is the only State in which the population decreased from the 2000 U.S. Census to the 2010 U.S. Census. During the same period, the Grand Traverse County population increased 12 percent to 86,986 and the Kalkaska County population increased approximately 4 percent to 17,153. The median age in years has increased by about 10 percent in Michigan and Grand Traverse County and about 13 percent in Kalkaska County. The population 65 years and over increased in Grand Traverse County and Kalkaska County by 28 percent and 25 percent, respectively. Persons under 5 years of age decreased in Kalkaska County and Michigan and increased approximately 4 percent in Grand Traverse County.

Table 1: Summary of 2010 Census Demographics

Description	Kalkaska County	Percent Change*	Grand Traverse County	Percent Change*	Michigan	Percent Change*
Population	17,153	+3.5	86,986	+12.0	9,883,640	-0.6
Persons Under 5 Years	1,043	-2.3	4,907	+3.9	596,286	-11.3
Persons 18 Years and Over	13,260	+7.5	67,791	+17.0	7,539,572	+2.7
Persons 65 Years and Over	2,837	+24.5	13,028	+28.4	1,361,530	+11.7
Median Age in Years	43.0	+13.2	41.3	+9.5	38.9	+9.6
Total Households	6,962	+8.3	35,328	+16.2	3,872,508	+2.3
Number of Housing Units	12,171	+12.5	41,599	+19.4	4,532,233	+7.0
Owner-Occupied Housing Units	5,751	+5.1	26,489	+12.6	2,793,342	+0.0

Source: U.S. Census Bureau (2010b)
*Percent change is the difference between the 2000 U.S. Census and the 2010 U.S. Census.

As indicated in **Table 1**, the total number of households increased by 16 percent in Grand Traverse County and by 8 percent in Kalkaska County. Both Grand Traverse and Kalkaska Counties have had a higher rate of growth in the number of housing units than Michigan overall. Although the number of owner-occupied housing units increased by about 13 percent in Grand Traverse County and 5 percent in Kalkaska County, overall, homeownership growth over 10 years in Michigan has been flat.

Table 2 summarizes data from the U.S. Census Bureau American Community Survey for Grand Traverse County, Kalkaska County, and Michigan. Household income is in 2010 dollars. Compared with Kalkaska County and Michigan, Grand Traverse County has higher incomes, fewer people below the poverty level, a lower unemployment rate, and more people with a higher education. Conversely, Kalkaska County has more people below the poverty level, a higher unemployment rate, and fewer people with a higher education than both Grand Traverse County and Michigan.

Table 2: Economic Characteristics and Educational Attainment

Description	Kalkaska County	Grand Traverse County	Michigan
Median Household Income (2010 $)	$39,350	$50,647	$48,432
Mean Household Income (2010 $)	$47,814	$66,488	$63,692
Below Poverty Level	13.0%	5.9%	10.6%
Unemployment Rate	15.4%	8.2%	11.5%
High School Graduate or Higher	84.8%	92.8%	88.0%
Bachelor's Degree of Higher	11.6%	28.9%	25.0%

Source: U.S. Census Bureau American Community Survey (2006–2010) 5-Year Estimates (2010a)

For the employed population 16 years and older, the top industry in Michigan, Grand Traverse County, and Kalkaska County is educational services, health care, and social assistance (U.S. Census Bureau, 2010a). The other leading industries in Michigan are manufacturing and retail trade. In Grand Traverse County, the other leading industries are retail trade; and arts, entertainment, recreation, accommodation, and food services. In Kalkaska County, the other leading industries are manufacturing; retail trade; and arts, entertainment, recreation, accommodation, and food services. **Table 3** summarizes employment by industry for Grand Traverse County, Kalkaska County, and Michigan for the employed population 16 years and older.

Table 3: Employment by Industry Estimates

Industry	Michigan	Grand Traverse County	Kalkaska County
Civilian employed population 16 years and over estimate	4,369,785	42,988	7,145
Agriculture, forestry, fishing and hunting, and mining	1.3%	1.6%	6.1%
Construction	5.3%	7.3%	8.4%
Manufacturing	17.6%	8.7%	11.5%
Wholesale trade	2.8%	2.9%	2.7%
Retail trade	11.6%	14.6%	11.5%
Transportation and warehousing, and utilities	4.2%	3.6%	5.7%
Information	1.9%	2.3%	0.8%
Finance and insurance, real estate and rental and leasing	5.7%	6.7%	4.5%
Professional, scientific, management, administrative and waste management services	8.9%	8.2%	6.7%
Educational services, and health care and social assistance	23.2%	22.6%	18.0%
Arts, entertainment, recreation, accommodation and food services	9.1%	12.5%	15.3%
Other services, except public administration	4.7%	4.9%	4.6%
Public administration	3.8%	4.1%	4.3%

Source: U.S. Census Bureau American Community Survey (2006–2010) 5-Year Estimates (2010a)

3 Existing and Future Without-Project Conditions

Understanding the existing condition and future without-project condition is critical to the planning process. The without-project condition represents the most likely conditions expected to exist in the future if a project is not implemented. More detailed information about the existing and future without-project conditions is available in the Detailed Project Report main text.

3.1 Existing Condition

Despite its attributes as an outstanding coldwater recreational fishery, the Boardman River system's ecological integrity is compromised by the presence of three dams within a 20-mile section of the river's main stream that composes the study area. These three dams include the Union Street, Sabin, and Boardman Dams. The presence of these dams disturbs the Boardman River ecosystem through habitat fragmentation and degradation, impacts to sediment movement, and thermally induced disruptions that adversely affect overall species diversity.

3.1.1 Union Street Dam

The Union Street Dam (**Figure 1**) is located in Traverse City at river mile 1.1. The dam was constructed in 1867 to supply power to a flour mill that no longer exists. Currently, the Union Street Dam is used to regulate the water level in Boardman Lake (**Figure 2**). A natural lake of 259 acres, Boardman Lake has increased to 339 acres with the damming of the river. The Union Street Dam consists of 250 lineal feet of earthen embankment, two spillways, and a fish ladder. Overall, the dam is reported to be in good condition and subject to good maintenance practices. Seepage at the downstream toe of the embankment and turbulent flow in some of the discharge culverts were recently observed, possibly indicating deterioration of the culverts. No major rehabilitation appears to be required in the immediate future to maintain dam safety. The fish ladder is designed for the passage of salmon and trout while preventing upstream travel of sea lamprey and appears to be structurally sound.

Figure 1: Union Street Dam, view of the dam

Figure 2: Boardman Lake, view of lake and public docks

From Union Street Dam downstream to Lake Michigan, habitat quality is generally good, with slight impairment and warmwater temperatures. This section is accessible to fish from Lake Michigan, and thus receives runs of fish including salmon, steelhead, sea lamprey, and sometimes lake sturgeon. The U.S. Fish and Wildlife Service (USFWS) treat this river segment to control the production of sea lamprey. The little available habitat data for Boardman Lake (**Figure 2**) suggests that aquatic macrophytes are common and zebra mussels are prevalent. This water body does provide an average fishery for sport fish such as walleye, smallmouth bass, and northern pike. Boardman Lake to Sabin Dam supports brown trout, smallmouth bass, and Chinook salmon. However, water in this segment can reach temperatures that are harmful to coldwater species.

3.1.2 Sabin Dam

The Sabin Dam (**Figure 3**), located at river mile 5.3, was constructed in 1906 and completely rebuilt in 1930. The dam was decommissioned in 2006 and power generation ceased. The Sabin Dam consists of earthen embankments, a powerhouse, a stop-log spillway, and a tainter gate spillway. A 1917 map shows a fish ladder just east of the powerhouse; this feature no longer exists. The structure exhibits minor cracks in the powerhouse superstructure, concrete deterioration on the downstream side of the powerhouse, a leaking roof, and minor corrosion at brick mortar joints and window lintels. No major rehabilitation appears necessary at this time to maintain dam safety. Routine maintenance is required.

The Sabin Dam impoundment provides a poor fishery. Although brown trout density is quite low in this segment, brown trout growth is quite high, with more than a third of brown trout greater than the legal minimum “keep” length.

Figure 3: Sabin Dam, view of spillway and control house

3.1.3 Boardman Dam

The Boardman Dam (**Figure 4**), also called Keystone Dam, is located at river mile 6.1. The dam consists of earthen embankments, an emergency spillway, and a concrete structure and penstock intake. Cass Road is located on the top of this dam and the bridge is directly tied to the dam structure. The Boardman Dam was constructed in 1894 and rebuilt in 1930; it was decommissioned in 2007. The dam exhibits significant cracking in the walls of the structure (which also serve as sub-structural supports for the bridge). The concrete beams that form the bridge superstructure are cracked and there is significant spalling on the fascia beams, exposing steel girders. The bridge barrier railing is in significant disrepair. The dam requires considerable repairs.

The Boardman Dam impoundment supports a fair-to-poor warmwater fishery. Rock bass and white sucker are the most abundant species present. Smallmouth bass and northern pike are common and bluegill, yellow perch, largemouth bass, and pumpkinseed sunfish are also present in low relative abundance. Upstream of the Boardman Dam, the former

Brown Bridge Dam was located at river mile 18.5. Removal of the Brown Bridge Dam and restoration of the waterway was completed in 2013. The habitat of the former Brown Bridge Dam impoundment serves as the best available reference for what conditions in the Boardman River would be like absent the impacts of the dams. The habitat quality is good to excellent, with stable banks, abundant gravel, and coldwater temperatures. Relatively high densities of brown and brook trout exist, with average growth rates.

Figure 4: Boardman Dam, view of intake structure

3.2 Future Without-Project Conditions

The Union Street, Sabin and Boardman Dams would remain in place, without any modifications. Traverse City and Grand Traverse County would have various responsibilities related to dam maintenance and regulatory requirements. In 2006, Grand Traverse County lowered the water level of Boardman Lake approximately 17 feet to meet spillway capacity requirements required by Michigan Dam Safety Regulations. This level is anticipated to remain as part of the without-project conditions.

Removal of the Brown Bridge Dam and restoration of the waterway was initiated by local interests in August 2012 and completed in 2013. Therefore, the Brown Bridge Dam was not part of the future without-project condition for this Feasibility Study. Removing the dam created an estimated 156 acres of new wetland area. It is likely that the removal of the dam mitigated thermal disruptions downstream of the former dam, and extended the existing coldwater fishery downstream.

The remaining dams would continue to fragment the Boardman River into three discontinuous segments, leading to continued loss of genetic diversity in the trout populations, as well as continued habitat degradation, and thermally induced species disruptions. Trout populations, biomass, and individual fish size would be expected to remain artificially low, and other coolwater fish populations would also experience negative effects. Species such as the lake sturgeon would not have access to the river.

3.3 Preliminary Screening of Measures

The purpose of this study is to identify and evaluate alternatives that would eliminate obstacles to the migration of fish and address the critical habitat features that can be improved on the Boardman River by removing or modifying the Union Street Dam, Sabin Dam, and/or Boardman Dam. The management measures were evaluated during a preliminary screening.

The preliminary screening evaluated the measures and eliminated measures that did not meet the objectives of the study or were not cost effective. The modification of the Sabin Dam or the Boardman Dam does not alleviate the thermal disruption of the impoundments and does not result in additional stream habitat for coldwater species. Although modifying the Sabin Dam or the Boardman Dam would allow for the passage of brook trout and longnose dace, no new coldwater stream habitat would be created for these species. Brook trout and longnose dace are exclusively coldwater species and are extremely sensitive to increased water temperatures. Modification of the Sabin Dam or the Boardman Dam would not lower water temperatures, whereas dam removal would lower the water temperature and increase available stream habitat. Increasing the habitat for lake sturgeon is contingent upon the modification of the Union Street Dam.

Three measures were removed from further consideration. In accordance with the USFWS desire to retain the Union Street Dam as a lamprey barrier, removal of the Union Street Dam was not considered further. Because modifications of the Sabin Dam and the Boardman Dam are costly, provide minimal habitat improvement, and do not meet the objectives of the project, these measures were removed from further consideration.

4 Alternatives

The remaining measures were combined to create eight alternatives, summarized in **Table 4**, to carry forward for further analysis. The alternatives were developed based on the individual measure that would be applied to each dam.

Table 4: Alternatives Selected for Further Analysis

Alternative	Union Street Dam	Sabin Dam	Boardman Dam
Alternative 1	No Action	No Action	No Action
Alternative 2	Modify	No Action	No Action
Alternative 3	Modify	Remove	No Action
Alternative 4	Modify	No Action	Remove
Alternative 5	Modify	Remove	Remove
Alternative 6	No Action	Remove	No Action
Alternative 7	No Action	No Action	Remove
Alternative 8	No Action	Remove	Remove

4.1 Alternative 1

Alternative 1 (No Action Alternative) consists of retaining and maintaining all of the dams, powerhouses, and spillways. No measures would be implemented to restore or improve coldwater habitat. Water levels and impoundment sizes would not change. The dams would not be modified to allow increased fish passage. The fish ladder at the Union Street Dam would be maintained, along with the MDNR Boardman River fish weir. The No Action Alternative is included in the analysis to provide a baseline against which the beneficial and adverse impacts of the with-project alternatives may be compared.

4.2 Alternative 2

Alternative 2 consists of modifying the Union Street Dam to improve fish passage with the establishment of a trap-and-transfer operation at the MDNR Boardman River fish weir. It would provide spawning and foraging habitat in Boardman Lake and the Boardman River up to Sabin Dam for lake sturgeon that were manually transferred past the weir/dam. The dam and existing fish ladder would remain in place to maintain the current Boardman Lake level, but downstream passage would be improved through the dam’s auxiliary spillway. The Sabin Dam would be maintained as it currently exists. The Boardman Dam would be retained and the pool elevation would remain lowered to meet the Dam Safety Act requirements of the MDEQ.

4.3 Alternative 3

Alternative 3 consists of modifying the Union Street Dam to improve fish passage with the establishment of a trap-and-transfer operation at the MDNR Boardman River fish weir. The dam and existing fish ladder would remain in place to maintain the current Boardman Lake level, but downstream passage would be improved through the dam’s auxiliary spillway. The Sabin Dam would be removed to allow a free-flowing river to be restored from the Boardman Dam to Boardman Lake. The Sabin Dam would be breached in the area of the auxiliary spillway. In this area the river and floodplain would be designed. All other parts of the dam (i.e. the powerhouses and other portions of the earthen embankment) would remain in place. The proposed river alignment would include engineered riffles/grade control structures at the former Sabin Dam location that would add stability to the restored channel in areas of relatively steep slopes. In addition to engineered rock riffles, other bank stabilization measures might be used at this location to redirect the channel and protect stream banks. The Boardman Dam would be retained and the pool elevation would remain lowered to meet the Dam Safety Act requirements of the MDEQ.

4.4 Alternative 4

Alternative 4 consists of modifying the Union Street Dam to improve fish passage with the establishment of a trap-and-transfer operation at the MDNR Boardman River fish weir. The dam and existing fish ladder would remain in place to maintain the current Boardman Lake level, but downstream passage would be improved through the dam's auxiliary spillway. The Sabin Dam would be maintained as it currently exists. The Boardman Dam would be removed and Boardman Pond would return to a more natural riverine state. The proposed river alignment would include engineered riffles/grade control structures at the former location of the Boardman Dam that would add stability to the restored channel in areas of relatively steep slopes. In addition to engineered rock riffles, other bank stabilization measures might be used at this location to redirect the channel and protect stream banks. The bridge and road construction project required as a result of moving the river channel is being undertaken by the Grand Traverse County Road Commission and is not part of the USACE Ecosystem Restoration Project.

4.5 Alternative 5

Alternative 5 consists of modifying the Union Street Dam to improve fish passage with the establishment of a trap-and-transfer operation at the MDNR Boardman River fish weir. The dam and existing fish ladder would remain in place to maintain the current Boardman Lake level, but downstream passage would be improved through the dam's auxiliary spillway. The Sabin Dam and the Boardman Dam would be removed to allow a free-flowing river to be restored from the Boardman Pond to Boardman Lake. The dams would be breached in the location of the historic channel. In this area the river and floodplain would be designed. All other parts of the dam (i.e. the powerhouses and other portions of the earthen embankment) would remain in place. The proposed river alignment would include engineered riffle/grade control structures at both dams that would add stability to the restored channel in areas of relatively steep slopes. In addition to engineered rock riffles, other bank stabilization measures might be used at the dams to redirect the channel and protect stream banks. The bridge and road construction project required as a result of moving the river channel is being undertaken by the Grand

Traverse County Road Commission and is not part of the USACE Ecosystem Restoration Project.

4.6 Alternative 6

Alternative 6 consists of retaining the Union Street Dam, along with the existing fish ladder and fish weir operation. The current fish ladder operation would continue. The Sabin Dam would be removed to allow a free-flowing river to be restored from the Boardman Pond Dam to Boardman Lake. The Sabin Dam would be breached in the area of the auxiliary spillway. In this area the river and floodplain would be designed. All other parts of the dam (i.e. the powerhouses and other portions of the earthen embankment) would remain in place. The proposed river alignment would include engineered riffles/grade control structures at the Sabin Dam that would add stability to the restored channel in areas of relatively steep slopes. In addition to engineered rock riffles, other bank stabilization measures might be used at the former Sabin Dam location to redirect the channel and protect stream banks. The Boardman Dam would be retained and the pool elevation would remain lowered to meet the Dam Safety Act requirements of the MDEQ.

4.7 Alternative 7

Alternative 7 consists of retaining the Union Street Dam, along with the existing fish ladder and fish weir operation. The Sabin Dam would be maintained as it currently exists. The Boardman Dam would be removed and Boardman Pond would return to a more natural riverine state. The Boardman dam would be breached through the earthen embankment in the location of the historic channel. In this area the river and floodplain would be designed. All other parts of the dam (i.e. the powerhouses and other portions of the earthen embankment) would remain in place. The proposed river alignment would include engineered riffles/grade control structures at the former Boardman Dam location that would add stability to the restored channel in areas of relatively steep slopes. In addition to engineered rock riffles, other bank stabilization measures might be used at this location to redirect the channel and protect stream banks. The bridge and road construction project required as a result of moving the river channel is being undertaken by the Grand Traverse County Road Commission and is not part of the USACE Ecosystem Restoration Project.

4.8 Alternative 8

Alternative 8 consists of retaining the Union Street Dam, along with the existing fish ladder and fish weir operation. The Sabin Dam and Boardman Dam would be removed to allow a free-flowing river to be restored from the Boardman Pond to Boardman Lake. The dams would be breached in the location of the historic channel. In this area the river and floodplain would be designed. All other parts of the dam (i.e. the powerhouses and other portions of the earthen embankment) would remain in place. The proposed river alignment would include engineered riffle/grade control structures at both dams that would add stability to the restored channel in areas of relatively steep slopes. In addition to engineered rock riffles, other bank stabilization measures might be used at the dams to redirect the channel and protect stream banks. The bridge and road construction project required as a result of moving the river channel is being undertaken by the Grand Traverse County Road Commission and is not part of the USACE Ecosystem Restoration Project.

5 Economic Analysis

The Water Resources Council publication *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (1983) directs Federal agencies to formulate plans that are economically and environmentally sound. Cost Effectiveness and Incremental Cost Analyses (CE/ICA) are recommended for evaluating ecosystem restoration projects. The environmental outputs are not expressed in monetary terms because there is currently no acceptable method for measuring many environmental outputs in monetary terms.

This CE/ICA follows the procedures specified by the USACE publication *Ecosystem Restoration in the Civil Works Program* (1995a) and the Institute for Water Resources (IWR) Report, *Evaluation of Environmental Investment Procedures Manual* (1995b). The CE/ICA tool from the IWR Planning Suite was used for the evaluation. The *Ecosystem Restoration in the Civil Works Program* (1995a) describes CE/ICA as follows:

> A CE analysis is conducted to ensure that the least cost alternatives are identified for various levels of environmental output. After the CE of the alternatives has been established, subsequent ICA is conducted to reveal and evaluate changes in costs for increasing levels of environmental output. Its primary purpose is the explicit comparison of the additional costs and additional outputs associated with alternative plans or plan features.

5.1 Environmental Outputs

Studies were undertaken to measure and quantify the habitat effects to fisheries and wetlands for each proposed alternative. The benefits relating to controlling the passage of sea lamprey control were also quantified. The fish habitat was assessed using habitat suitability index (HSI) models developed by the USFWS. By using existing HSI models and modifying them with regional field data, both the current status of the Boardman River and the results of implementing the alternatives can be analyzed in terms of habitat suitability for each of the selected fish species. This analysis produces alternative-specific HSI scores, which can be used to estimate how critical fish species would be affected by each alternative. The HSI scores for each alternative contributed to the estimated average annual habitat units (AAHUs) for each alternative. To assess wetland habitat, the Michigan Rapid Assessment Method (MiRAM) was used to generate a function and value score for the wetlands impacted by each alternative. The wetland AAHUs were calculated using the MiRAM score and the wetland size. The benefits related to controlling sea lamprey were quantified as AAHUs using miles of river protected by a physical barrier to prevent infestation. The results of these assessments are then considered when selecting alternatives and can be used to improve the habitat of fisheries within the Boardman River. More detailed information relating to the AAHUs assessments is available in **Appendix E**.

The HSI and sea lamprey control assessments were evaluated by river segment. The Boardman River is divided into 10 segments. **Table 5** describes the locations and lengths of the Boardman River segments. **Figure 5** illustrates the location of the segments on the Boardman River as described in **Table 5**.

Table 5: Boardman River Segments

Segment Number	Location	Length (miles)
1	From Union Street Dam downstream to Lake Michigan and Hospital Creek, also known as Kids Creek	1.14
2	Union Street Dam impoundment, also known as Boardman Lake	2.14
3	From Sabin Dam downstream to Union Street Dam impoundment	2.15
4	Sabin Dam impoundment (Sabin Pond) upstream to Boardman Dam	1.04
5	Boardman Dam impoundment, also known as Boardman Pond or Keystone Pond	1.34
6	From Brown Bridge Dam downstream to Boardman Dam impoundment	12.03
7	Brown Bridge Dam impoundment, also known as Brown Bridge Pond	1.63
8	From the Forks downstream to the Brown Bridge Dam impoundment	6.95
9A	North Branch of the Boardman River	3.00
9B	South Branch of the Boardman River	3.00

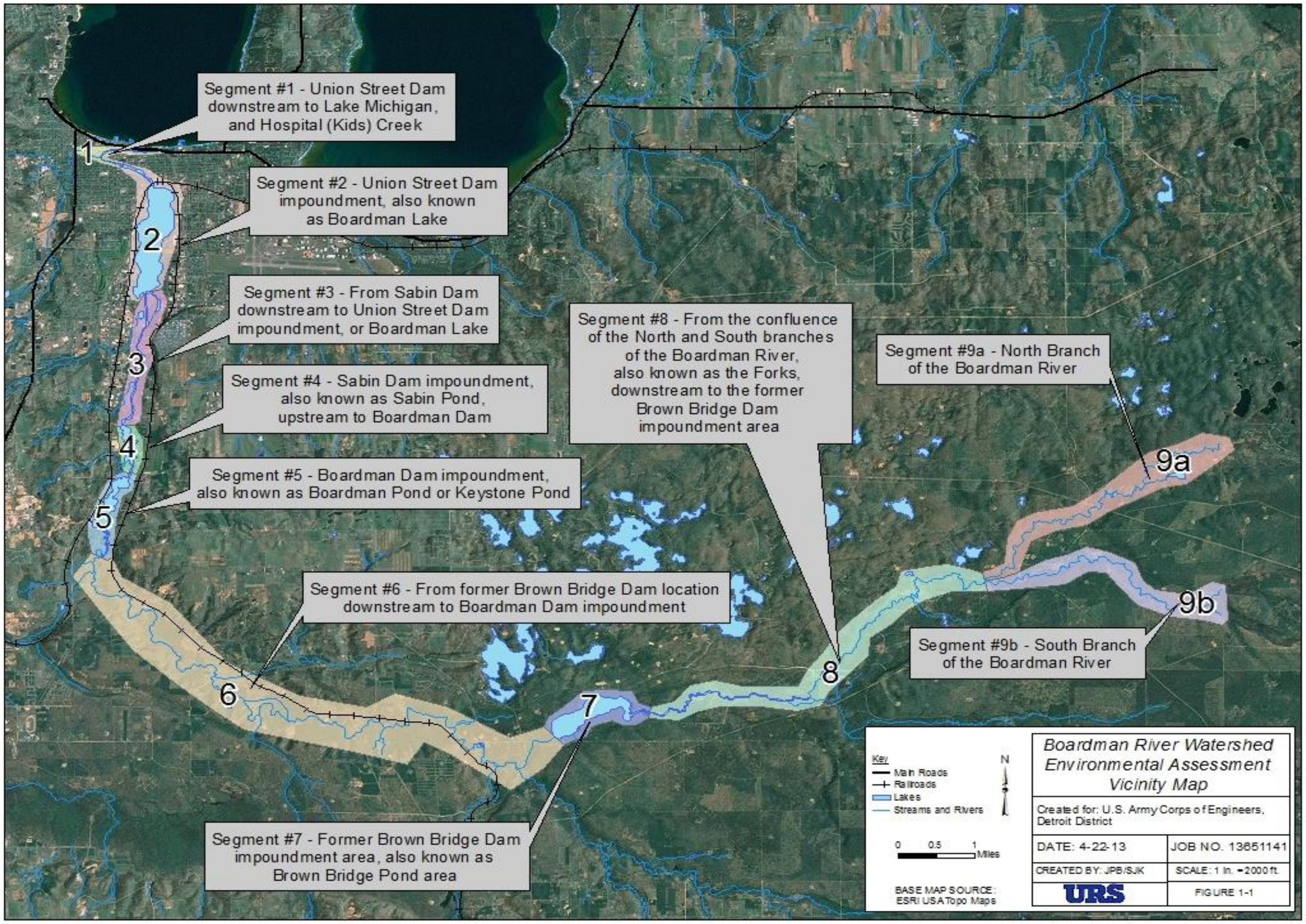

Figure 5: Location of Segments on Boardman River

5.1.1 Fish Habitat

The conversion of an impoundment to riverine habitat would provide more usable habitat for the brook trout, longnose dace, and lake sturgeon by lowering water temperatures and increasing the current, which seem to be the limiting factors for these fish species along with, to a lesser degree, substrate type and riffle habitat.

HSI scores were evaluated by river segment and include only the river segments that would be affected. The scores assume that the Brown Bridge Dam was removed. The scores also account for habitat connectivity (i.e., whether migratory fish, such as lake sturgeon, can pass through the Union Street Dam).

HSI scores for lake sturgeon predictably increase for each alternative that provides access to additional reaches of the Boardman River. Any viable alternative to increase sturgeon habitat must include passage through the Union Street Dam. Fish passage through just the Union Street Dam significantly increases HSI scores by giving the fish access to Boardman Lake and the main stem of the river. Removal of the Sabin Dam also increases the HSI scores. However, the largest increase comes with the removal of the Sabin and Boardman Dams, which would provide access to the entire Boardman River system. Alternative 5, which incorporates removal of both the Sabin and Boardman Dams and the modification of Union Street Dam would greatly increase the available habitat in the Boardman River for lake sturgeon by providing access to riverine habitat that is predicted to be suitable for lake sturgeon spawning and embryo development. The species-specific HSI scores for each river segment were used to calculate the AAHUs for each alternative. The AAHUs associated with the brook trout, longnose dace, and lake sturgeon were combined when applicable. **Table 6** presents the total and the net AAHUs estimated for each alternative for improvements to fisheries. The net AAHU is the difference between the with-project and without-project (No Action Alternative) values.

Table 6: Fisheries Average Annual Habitat Units

Alternative	Fisheries AAHUs	Fisheries Net AAHUs
1. No Action	2,908	0
2. Modify Union	2,973	65
3. Modify Union, Remove Sabin	3,176	268
4. Modify Union, Remove Boardman	3,233	325
5. Modify Union, Remove Sabin and Boardman	3,928	1,020
6. Remove Sabin	3,089	181
7. Remove Boardman	3,168	260
8. Remove Sabin and Boardman	3,349	441

AAHUs = average annual habitat units

5.1.2 Wetland Habitat

Wetland habitat was assessed using MiRAM scores. MiRAM is a rating system meant for comparing the functional value of a wetland to other wetlands in Michigan, regardless of ecological type. The quantitative rating is a series of metrics designed to provide a numerical score that reflects the total functional value of a wetland, which includes a wetland's ecological condition (integrity) and its potential to provide ecological and societal services (functions and values).

MiRAM assessments favor wetlands associated with river restoration because these wetlands typically include high plant diversity, forested habitat, complex hydrology, and multiple habitat features, and they lack invasive species. When wetland size is taken into account, alternatives involving dam removal score high because of the additional acres of wetland habitat that is anticipated to form from draining of the impoundments. The total and net AAHUs for each alternative generated from the MiRAM analysis are presented in **Table 7**.

Table 7: Wetland Average Annual Habitat Units

Alternative	Wetland AAHUs	Wetland Net AAHUs
1. No Action	1,726	0
2. Modify Union	1,726	0
3. Modify Union, Remove Sabin	3,371	1,645
4. Modify Union, Remove Boardman	3,142	1,416
5. Modify Union, Remove Sabin and Boardman	4,787	3,061
6. Remove Sabin	3,371	1,645
7. Remove Boardman	3,142	1,416
8. Remove Sabin and Boardman	4,787	3,061

AAHUs = average annual habitat units

5.1.3 Sea Lamprey Control

For each alternative, sea lampreys would be controlled by the existing Union Street Dam. Because the Union Street Dam is considered to be a barrier impermeable to sea lamprey, Alternative 1 (the No Action Alternative), receives the same score for controlling sea lamprey as the other alternatives, 3,328 AAHUs. Therefore, the net AAHU for sea lamprey control for each alternative is zero. The results of the sea lamprey control analysis indicate that modifying the Union Street Dam to continue preventing the migration of sea lamprey is the best technique to limit this invasive species' impact on the Boardman River.

5.1.4 Average Annual Habitat Units

The net AAHUs scores from the fisheries, wetlands, and sea lamprey control analyses are combined, and the sums generate the total AAHUs for each alternative. The net AAHU is the difference between the with-project and the without-project (No Action Alternative) values. The net AAHUs are used in the CE/ICA. A summary of the net AAHUs is presented in **Table 8**. Alternative 5 would produce the most AAHUs, while Alternative 2 would produce the fewest additional AAHUs.

Table 8: Summary of Net Average Annual Habitat Units

Alternative	Fisheries AAHUs	Wetlands AAHUs	Total Net AAHUs
1. No Action	0	0	**0**
2. Modify Union	65	0	**65**
3. Modify Union, Remove Sabin	268	1,645	**1,913**
4. Modify Union, Remove Boardman	325	1,416	**1,741**
5. Modify Union, Remove Sabin and Boardman	1,020	3,061	**4,081**
6. Remove Sabin	181	1,645	**1,826**
7. Remove Boardman	260	1,416	**1,676**
8. Remove Sabin and Boardman	441	3,061	**3,502**

AAHUs = average annual habitat units

5.2 Project Costs

All costs were calculated in terms of present value and then annualized. The average annual cost (AAC) is based on 2012 price levels, the current fiscal year (FY14) Federal discount rate of 3.50 percent, and a 50-year period of analysis. The discount rate, specified by the Water Resources Council, is to be used by Federal agencies in the formulation and evaluation of water and land resource plans. Costs include all expenditures required to implement the alternatives. More detailed cost information is available in **Appendix C**.

Construction costs for the Sabin and Boardman Dams include earthworks and site preparation, stream restoration, dam removal, incidental construction, and re-vegetation. The Union Street Dam construction costs include fish lift costs, demolition of the existing spillway, earthworks and site clearing, structural concrete, and fencing. Administration costs for the Sabin and Boardman Dams include soil sampling/analysis during the planning, engineering and design phase and a Phase I analysis which would be completed 6 months prior to the acquisition of real estate. The interest during construction for each alternative is calculated based on a period of 6 months for construction. The environmental monitoring cost for each alternative is $10,000 per year for 3 years after construction is complete and the present value is $28,000. Monitoring costs include temperature and dissolved oxygen monitoring; fish sampling to assess fish species diversity and abundance; and monitoring the channel and habitat structure stability.

Alternative 1, the No Action Alternative, assumes the three dams would be maintained for another 50 years; the present value of the necessary improvements and maintenance is approximately $1,929,100, an AAC of $82,200. This cost assumes an annual operation and maintenance cost of $20,000 for each dam, a $500,000 repair of stop log structures at the Union Street Dam, and $20,000 each for the Sabin and Boardman Dams to repair degradation of structures. Cass Road is located on the top of the Boardman Dam. The operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) cost for the No Action Alternative does not include costs to repair Cass Road Bridge, only the costs to maintain the existing dams.

The OMRR&R cost for the Union Street Dam modification is approximately $24,000 (present value of $562,900), which includes trap-and-transfer costs. After their removal, the Sabin and Boardman Dams would not have annual OMRR&R costs. For each alternative, OMRR&R is calculated for the entire system, including all three dams. For alternatives that include the removal of a dam or dams, the OMRR&R is associated with the remaining dam(s).

Table 9 summarizes the estimated cost for each alternative. All anticipated study costs are included in the project costs. However, once study costs are incurred, they become sunk costs and are no longer included in the project costs. Because the study costs associated with this Feasibility Study have already been incurred, these costs are considered sunk costs and are not included in the CE/ICA. The net present value is the difference between the with-project and without-project costs. The net AACs are used in the CE/ICA.

Table 9: Summary of Alternative Costs[1]

Description	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Real Estate	-	$5,200	$38,200	$67,000	$100,000	$33,000	$61,800	$94,800
Construction	-	$459,800	$2,147,400	$4,345,800	$6,033,400	$1,687,600	$3,886,000	$5,573,600
Engineering	-	$92,000	$429,500	$869,200	$1,206,700	$337,500	$777,200	$1,114,700
Administration	-	$23,000	$142,400	$252,300	$361,700	$119,400	$229,300	$338,700
Contingency	-	$115,000	$536,900	$1,086,400	$1,508,300	$421,900	$971,500	$1,393,400
Interest During Construction	-	$5,000	$23,700	$47,700	$66,400	$18,700	$42,700	$61,300
Present Value of Monitoring Cost	-	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000
Present Value of OMRR&R	$1,929,100	$1,539,800	$1,051,400	$1,051,400	$562,900	$1,440,600	$1,440,600	$952,200
Present Value of Total Cost	$1,929,100	$2,267,800	$4,397,500	$7,747,800	$9,867,400	$4,086,700	$7,437,100	$9,556,700
Net Present Value	$0	**$338,700**	**$2,468,400**	**$5,818,700**	**$7,938,300**	**$2,157,600**	**$5,508,000**	**$7,627,600**
Average Annual Cost	**$0**	**$14,400**	**$105,200**	**$248,100**	**$338,400**	**$92,000**	**$234,800**	**$325,200**

OMRR&R = operation, maintenance, repair, replacement, and rehabilitation
Note: Average annual costs were calculated using the FY14 Federal discount rate of 3.50 percent and a 50-year period of analysis. All costs are in 2012 dollars and were rounded to the nearest hundred. The OMRR&R costs include all three dams. The net present value is the difference between the with-project and the without-project costs.

[1] Less sunk Feasibility Study costs per IWR Report 93-R-12, *National Economic Development Procedures Manual* – National Economic Development Costs, Section 2.12.5(A), p. 56 and *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, March 1983, p. 97.

5.3 Cost Effectiveness Analysis

A CE analysis is conducted to ensure the least-cost alternatives are identified for various levels of environmental output. The CE analysis begins with a comparison of the AAC and the AAHUs of each alternative to identify the least-cost alternative for every level of environmental output considered. The results of the CE analysis are summarized in **Table 10**.

Table 10: Cost Effectiveness Analysis Results

Alternative	AAC	AAHUs	AAC/ AAHU	Cost Effective (Y/N)
1. No Action	$0	0	$0	Y
2. Modify Union	$14,400	65	$222	Y
3. Modify Union, Remove Sabin	$105,200	1,913	$55	Y
4. Modify Union, Remove Boardman	$248,100	1,741	$143	N
5. Modify Union, Remove Sabin and Boardman	$338,400	4,081	$83	Y
6. Remove Sabin	$92,000	1,826	$50	Y
7. Remove Boardman	$234,800	1,676	$140	N
8. Remove Sabin and Boardman	$325,200	3,502	$93	Y

AAC = average annual cost, AAHUs = average annual habitat units
Note: Average annual costs were calculated using the FY14 Federal discount rate of 3.50 percent and a 50-year period of analysis. All costs are in 2012 dollars.

Figure 6 plots the environmental output of each alternative against the cost of each alternative to create the "cost effectiveness frontier," as indicated by an imaginary line passing through all cost effective alternatives. Any alternatives above and to the left of the cost effectiveness frontier line are not cost effective. Alternatives 4 and 7 are not cost effective because Alternative 6 can produce more AAHUs at less cost. Therefore, Alternatives 4 and 7 are removed from further consideration. Alternatives 1, 2, 3, 5, 6, and 8 were determined to be cost effective.

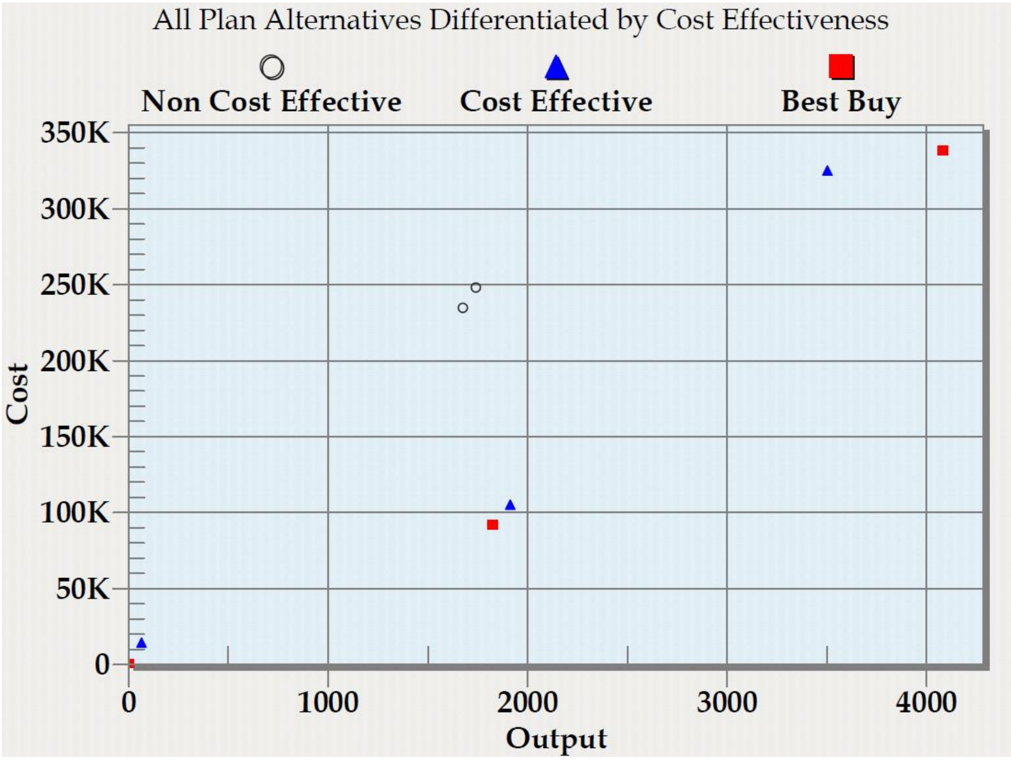

Figure 6: Cost Effectiveness Frontier

5.4 Incremental Cost Analysis

An ICA of the cost effective solutions is conducted to reveal and evaluate incremental changes in costs for increasing levels of environmental outputs. The ICA compares the environmental outputs with economic costs of alternatives to identify the alternative that has the lowest incremental cost per AAHU. Although the ICA does not provide a discrete decision criterion, it allows for the comparison of the changes in costs and AAHUs on which such decisions are made. The ICA can be used as a decisionmaking tool by progressively proceeding through the available levels of outputs and asking whether the habitat value of the additional AAHUs in the next available level of output is worth the additional cost.

Of the cost effective alternatives, the alternative with the lowest incremental cost per unit of output of all alternatives is the first "best buy" alternative. Then, all cost effective alternatives are compared to the first best buy alternative in terms of increments of cost and increases in increments of output. The alternative with the next lowest incremental cost per unit of output is the second best buy alternative and so on. This is an iterative process whereby the remaining cost effective alternatives are screened by repeatedly evaluating which alternative has the lowest incremental AAC per incremental AAHU. For this study, this screening analysis eliminated some alternatives that have lower total costs but are relatively inefficient in production. From the ICA, Alternatives 5 and 6 were identified as the best buy alternatives.

Table 11 presents a summary of the ICA. The ICA results show the additional cost that would be incurred to gain additional AAHUs for each successive level of attainable AAHUs. Because Alternative 1 entails making no changes, the concept of incremental values does not apply. Alternatives 5 and 6 were identified as best buy alternatives.

Table 11: Results of the Incremental Cost Analysis

Alternative	AAC	AAHUs	Incremental Cost	Incremental AAHUs	Incremental Cost per AAHU	Best Buy
1. No Action	$0	-	-	-	-	Y
2. Modify Union	$14,400	65	$14,400	65	$222	
6. Remove Sabin	$92,000	1,826	$77,600	1761	$44	Y
3. Modify Union, Remove Sabin	$105,200	1,913	$13,200	87	$152	
8. Remove Sabin and Boardman	$325,200	3,502	$220,000	1589	$138	
5. Modify Union, Remove Sabin and Boardman	$338,400	4,081	$13,200	579	$23	Y

AAC = average annual cost, AAHUs = average annual habitat units
Note: Average annual costs were calculated using the FY14 Federal discount rate of 3. 50 percent and a 50-year period of analysis. All costs are in 2012 dollars.

5.5 Incidental Benefits

The presence of the dams has disrupted the Boardman River ecosystem and has reduced the populations of trout and other coldwater fish species. For each dam that would be removed, the populations of trout and other coldwater fish species are anticipated to increase as the populations of warmwater fish species decline. Fishing for warmwater fish species may decrease; however, other fisheries nearby would serve as substitute fishing sites, whereas coldwater fisheries are less common in the area. Canoeing and kayaking on the Boardman River requires portaging at each existing dam. Dam removal may increase canoeing and kayaking trips on the Boardman River, as the river would be more continuous.

6 Summary

Alternatives 5 and 6 were identified as best buy alternatives, with Alternative 5 producing the most AAHUs of all the alternatives. The CE/ICA is not intended to lead to a single best solution (as in an economic cost-benefit analysis); however, the analyses improve the quality of decisions by ensuring a supportable approach for considering and selecting an alternative.

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